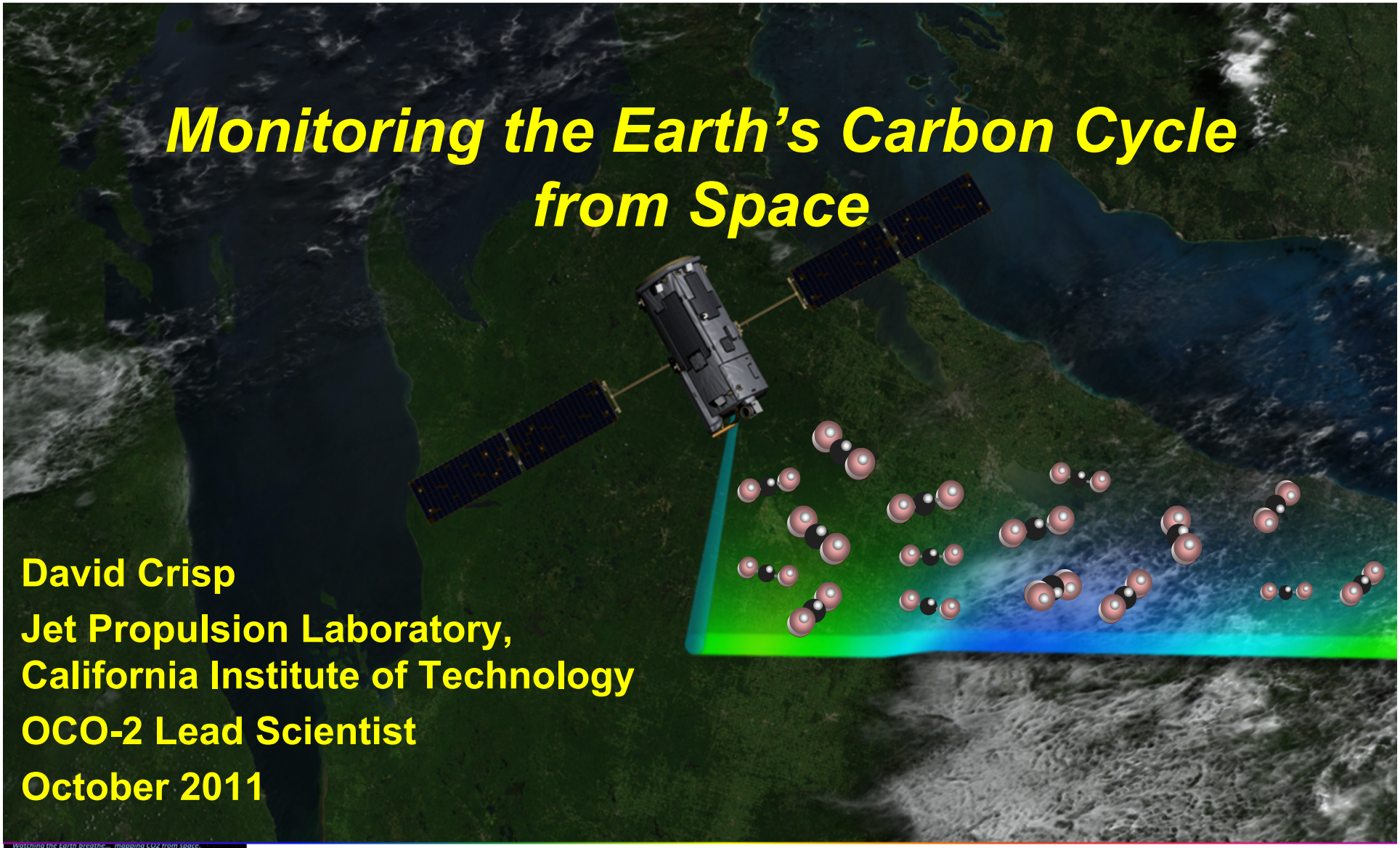
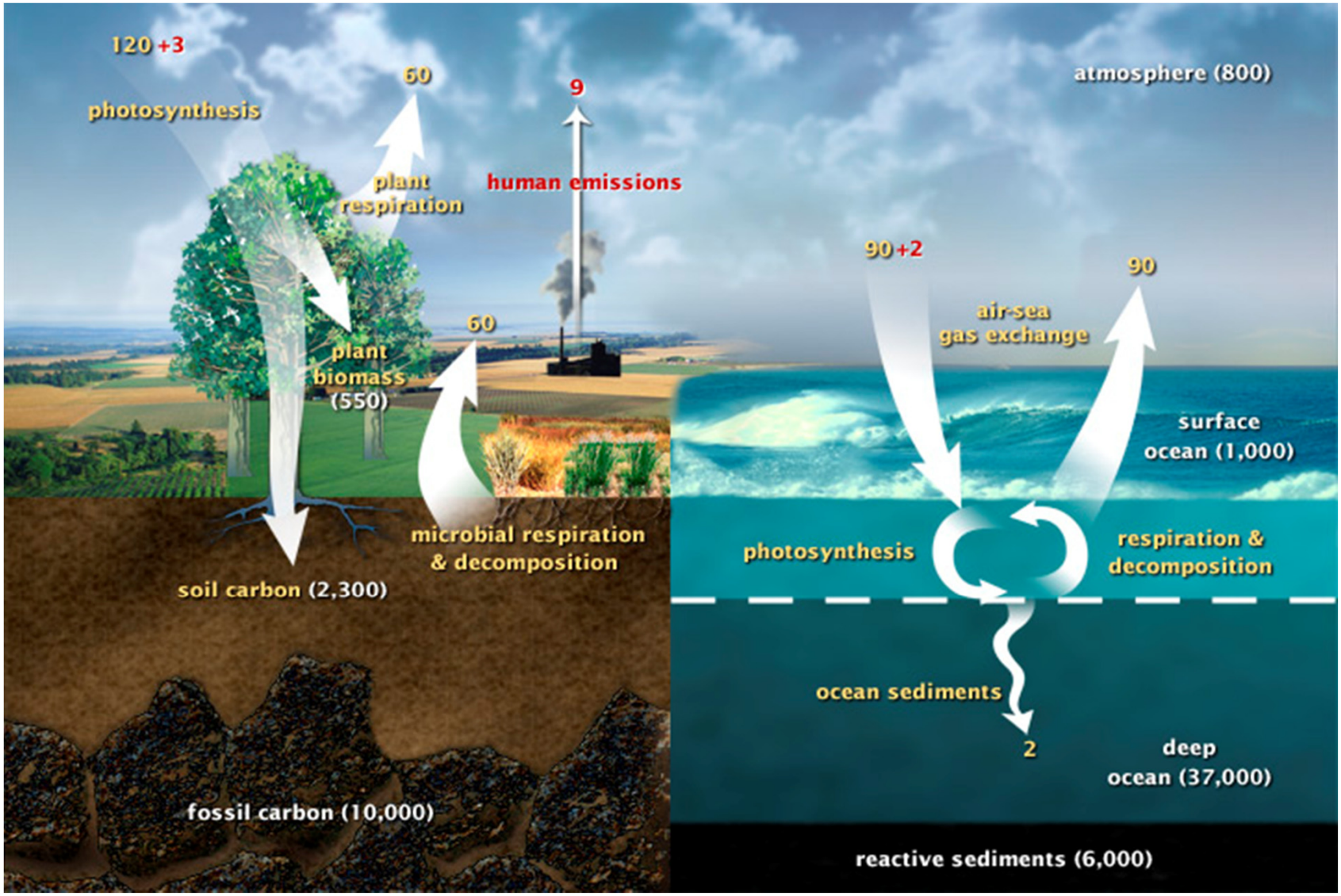
Monitoring the Earth's Carbon Cycle from Space



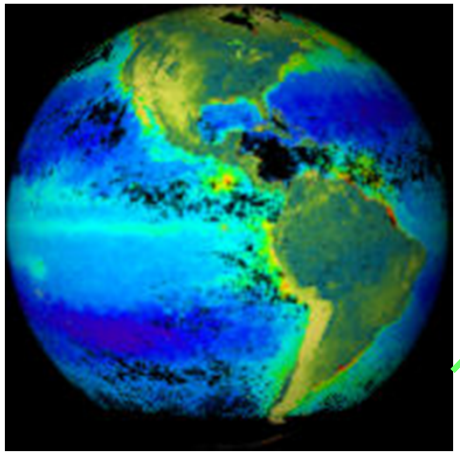
David Crisp
Jet Propulsion Laboratory, California Institute of Technology
OCO-2 Lead Scientist
October 2011

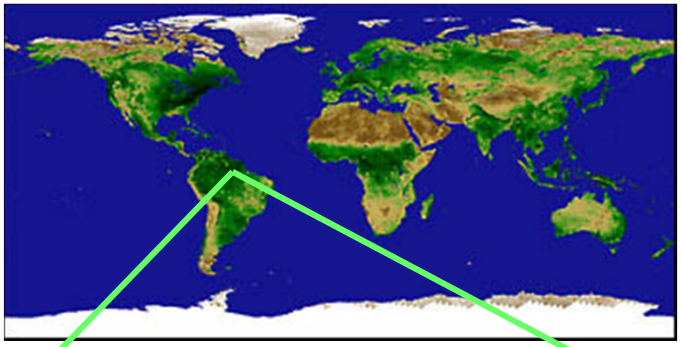
Copyright 2011 California Institute of Technology.
Government sponsorship acknowledged.

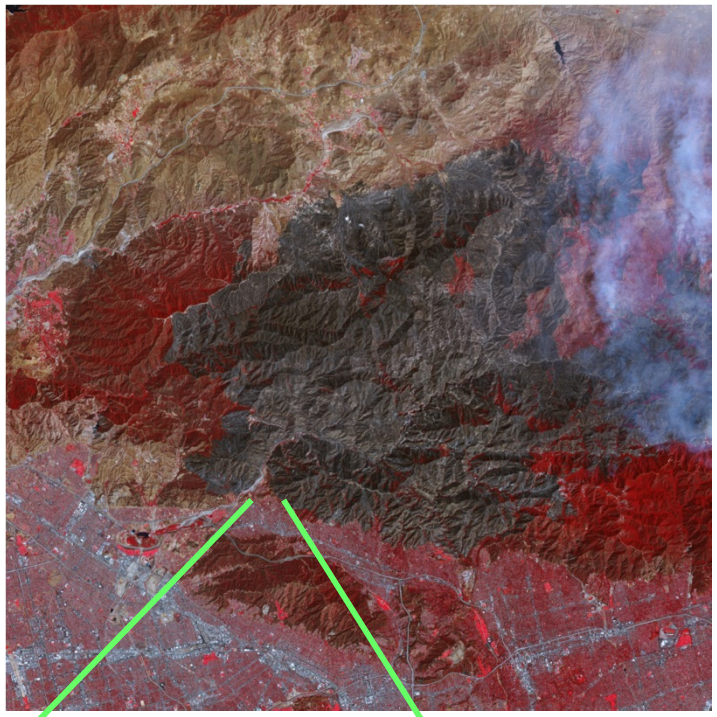
The Carbon Cycle

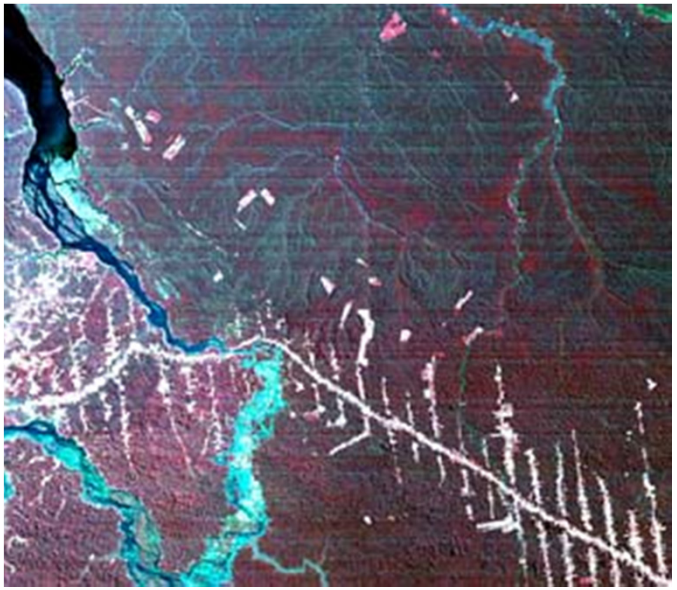


Existing Space Based Observations

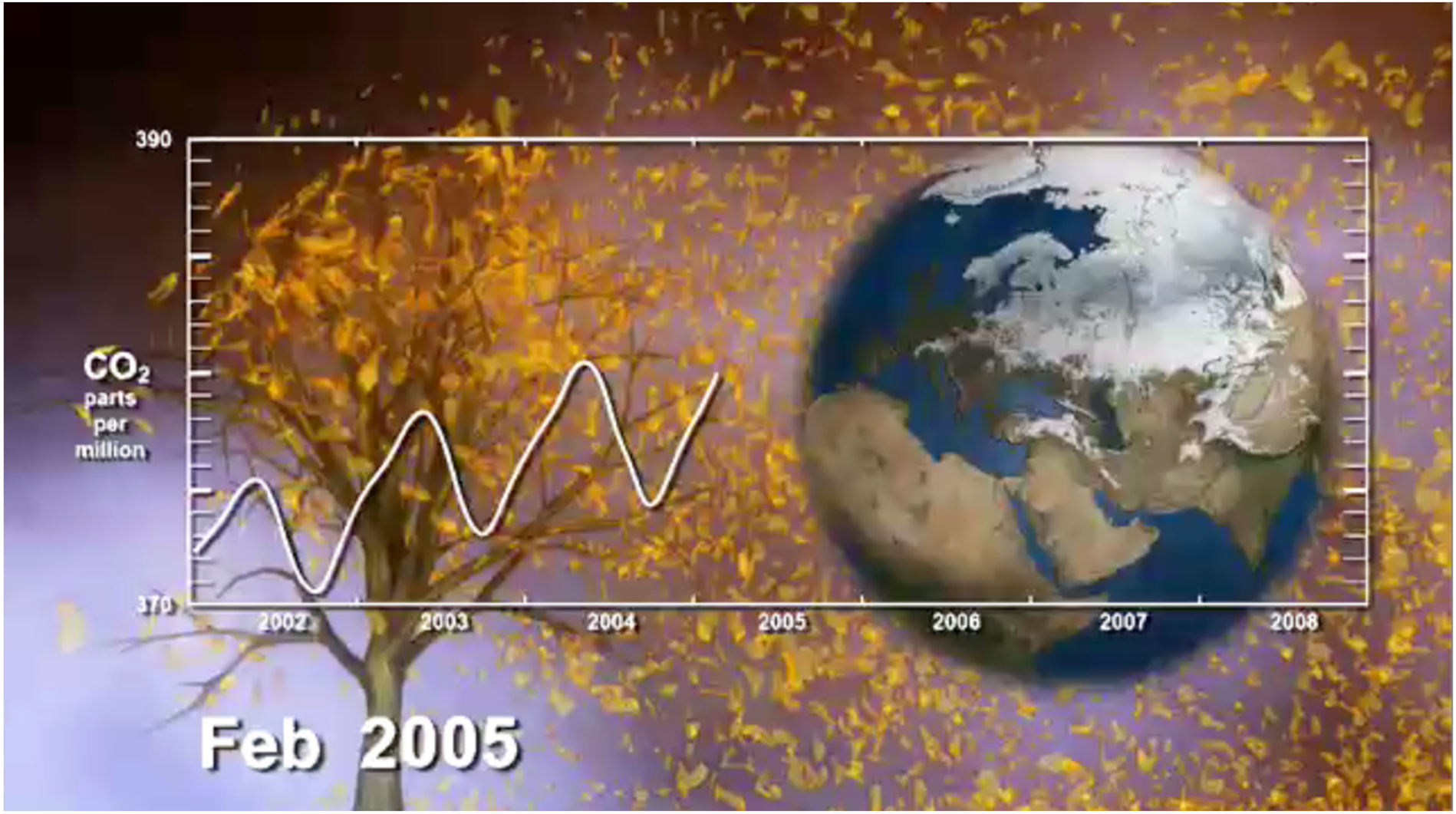


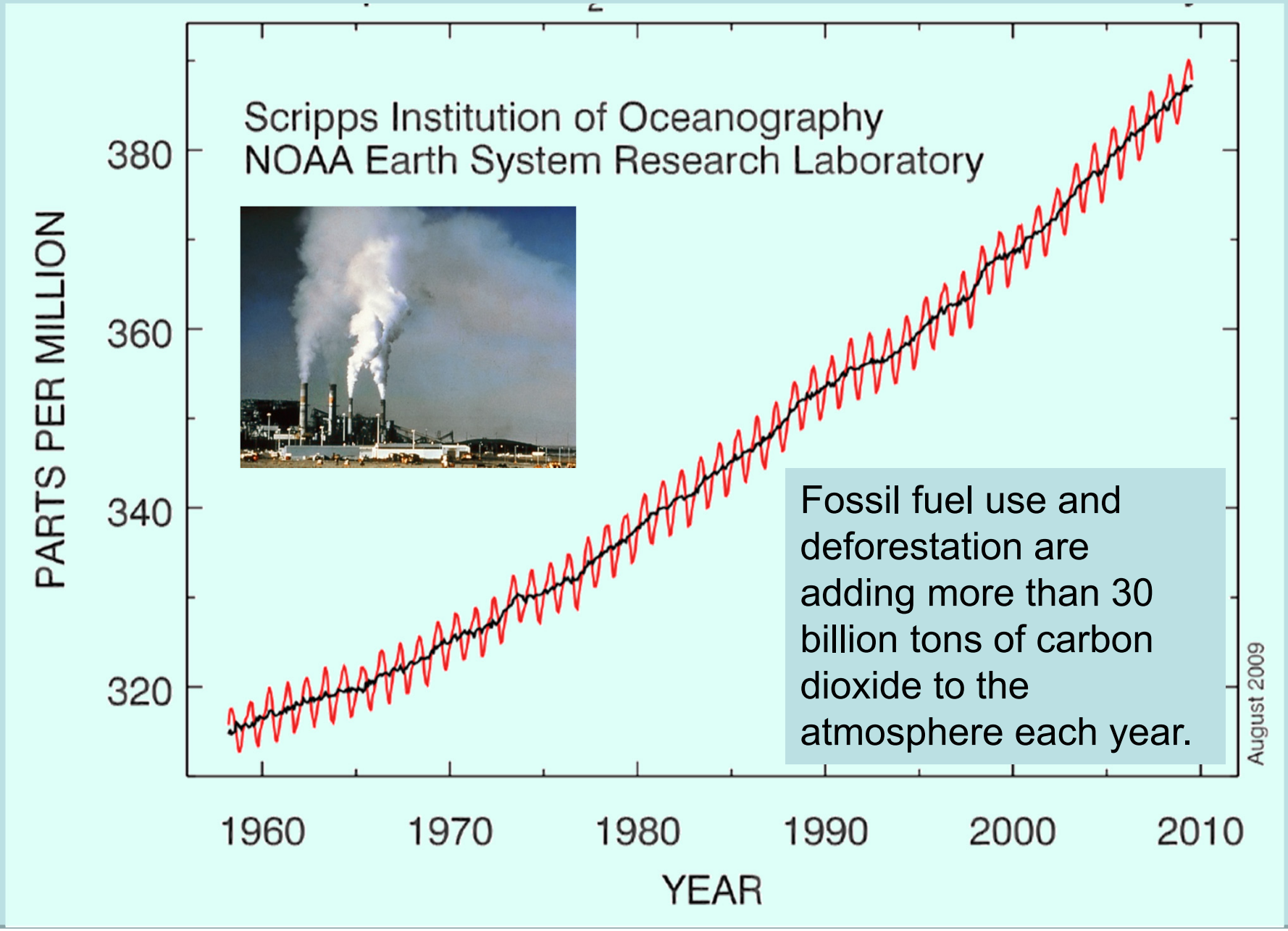






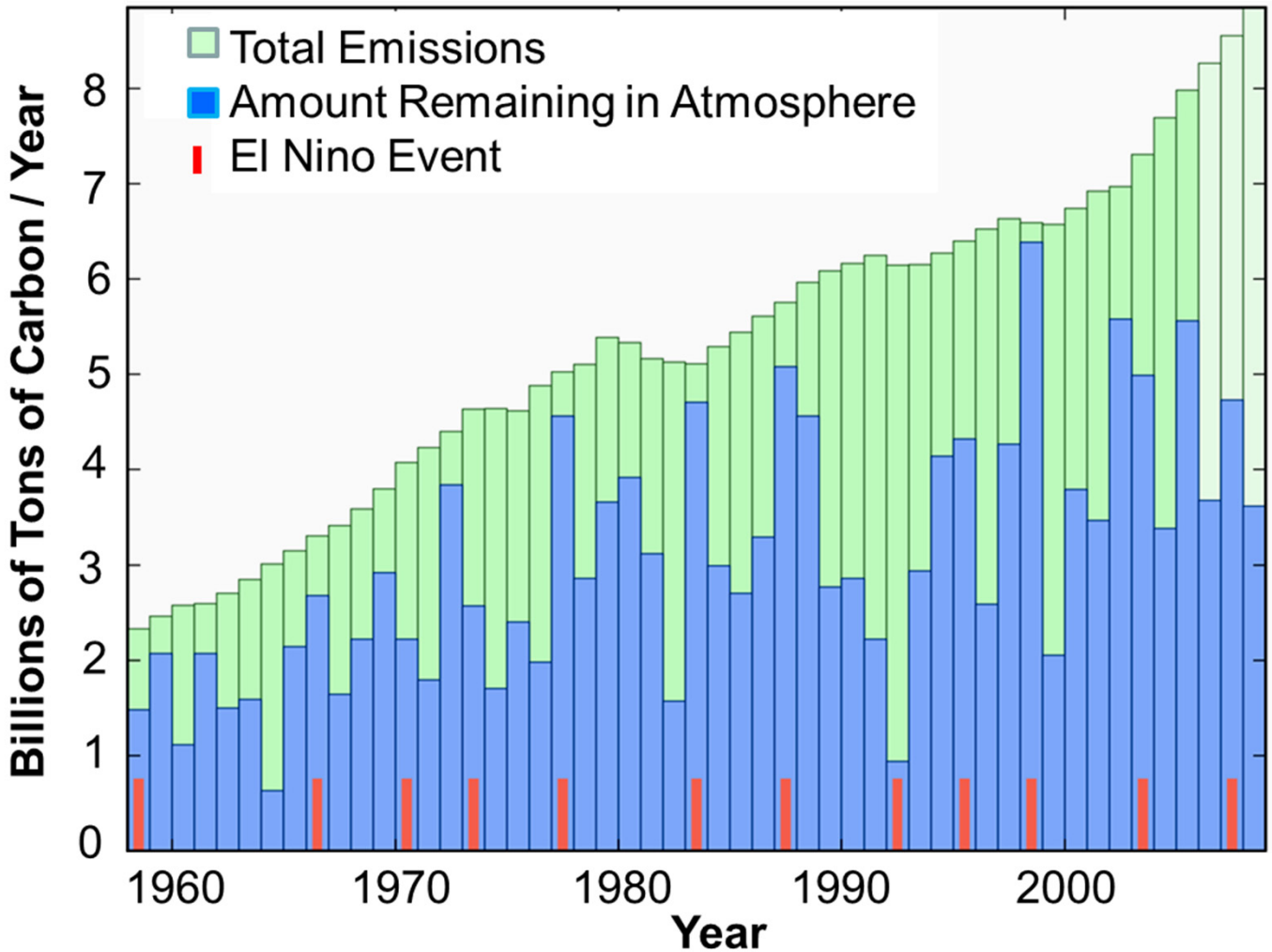
Carbon Dioxide and the Carbon Cycle





Fossil fuel use and deforestation are adding more than 30 billion tons of carbon dioxide to the atmosphere each year.

What Processes Regulate CO_2 Sinks?



Why does the amount of CO_2 that stays in the atmosphere change so much from year to year?

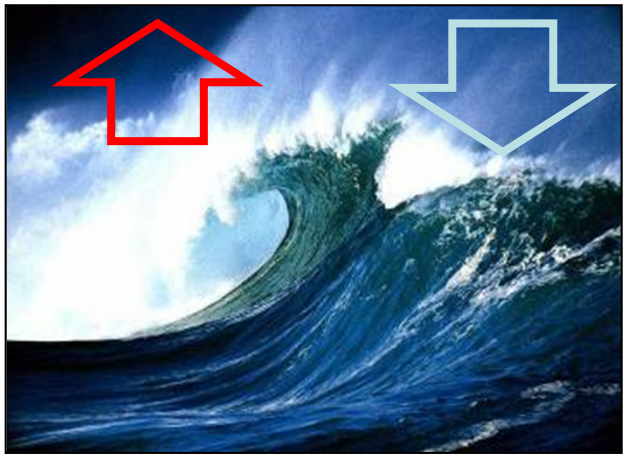
We don't know.

What Controls Atmospheric Carbon Dioxide?

- Natural systems including the ocean and plants on land both absorb and emit carbon dioxide to the atmosphere

- Currently, these natural systems are
  - absorbing about half of the carbon dioxide emitted by human activities
  - limiting the rate of carbon dioxide buildup and its impact on the Earth's climate

- Fundamental questions:
  - What processes are responsible for absorbing this CO_2?
  - Why does the sink strength vary dramatically from year to year?
  - Will the nature, location and strength of these CO_2 sinks change in the future?



Measuring CO_2 Released by Fossil Fuels

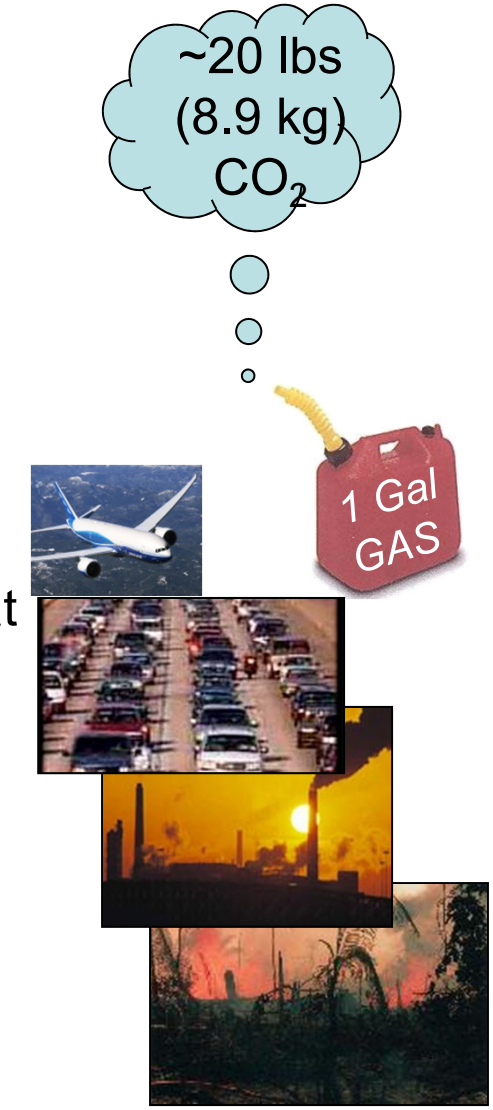
CO_2 is a product of human activity:

- Burning a gallon of gasoline, diesel, or jet fuel emits 9 to10 kg (20 lbs) of CO_2 into the air

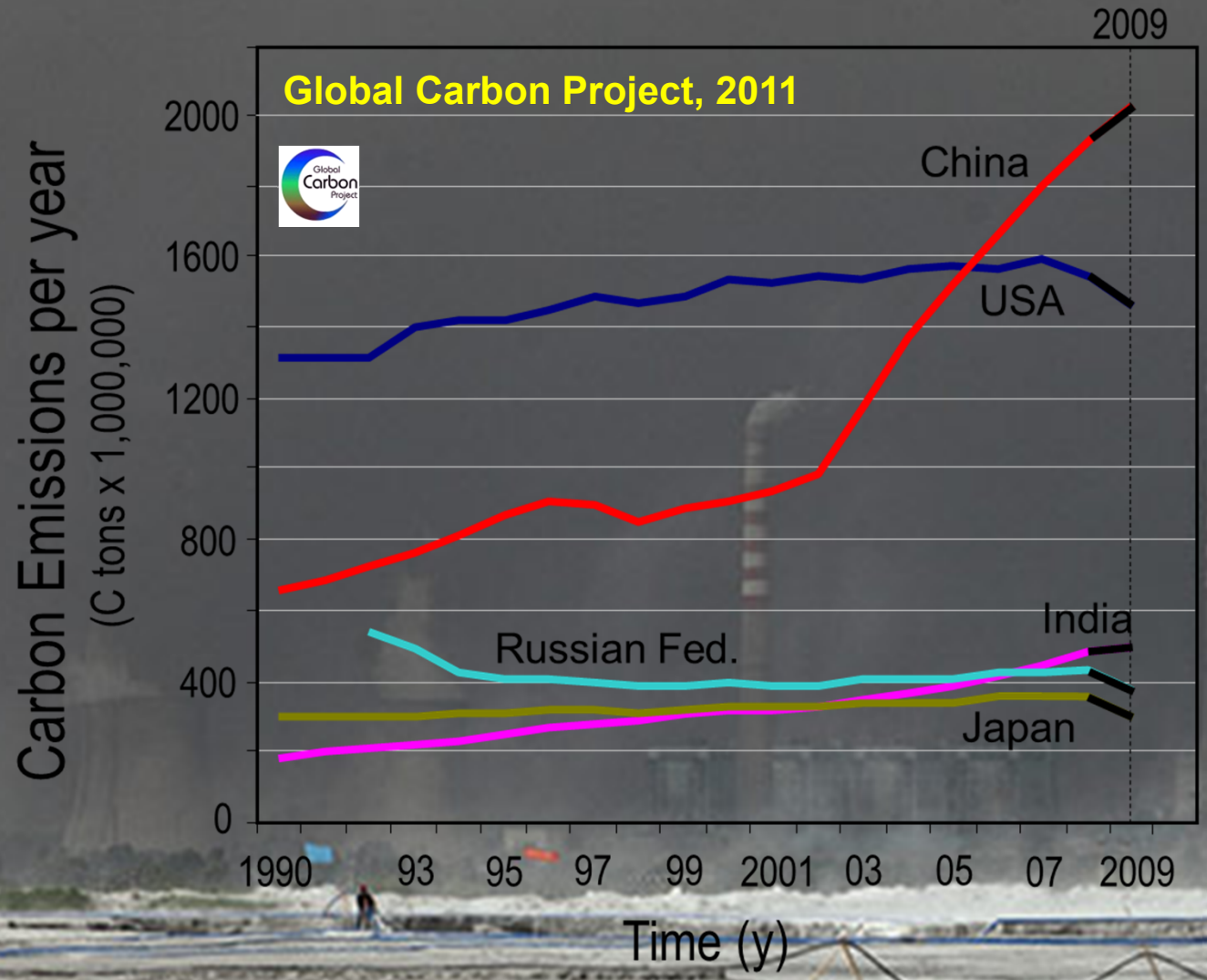
If we assume that the average American drives burns 20 gallons of gas per week, the annual CO_2 emission is:
20 gallons/week*19.6 lbs CO_2 /gallon * 52 weeks/year =
20,384 lbs CO_2 /year = 10.1 tons of CO_2/year

This consistent with available estimates, which show to that the average American produces ~20 tons of CO_2/year
– Transportation: 37%, Utilities: 41%, Other Industry: 11%

For comparison:
The average European produces ~14 tons CO_2/year
The average Japanese produces ~9.6 tons CO_2/year
The average Chinese produces ~2 tons CO_2/year



Fossil Fuel CO_2 Emissions: Top Emitters



In recent years, the largest increases in fossil fuel emissions have occurred in developing countries.

Emissions by some developed countries declined due to the global economic crisis.

China is now the largest single emitter, but its per capita emissions are still well below those in the U.S.

Orbiting Carbon Observatory

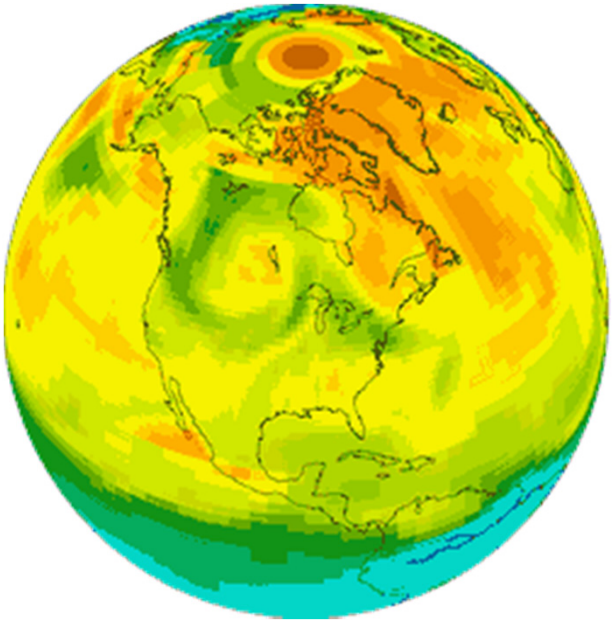
Global Measurements from Space are Essential for Monitoring Atmospheric CO_2

To limit the rate of atmospheric carbon dioxide buildup, we must

- Control emissions associated with human activities
- Understand & exploit natural processes that absorb carbon dioxide

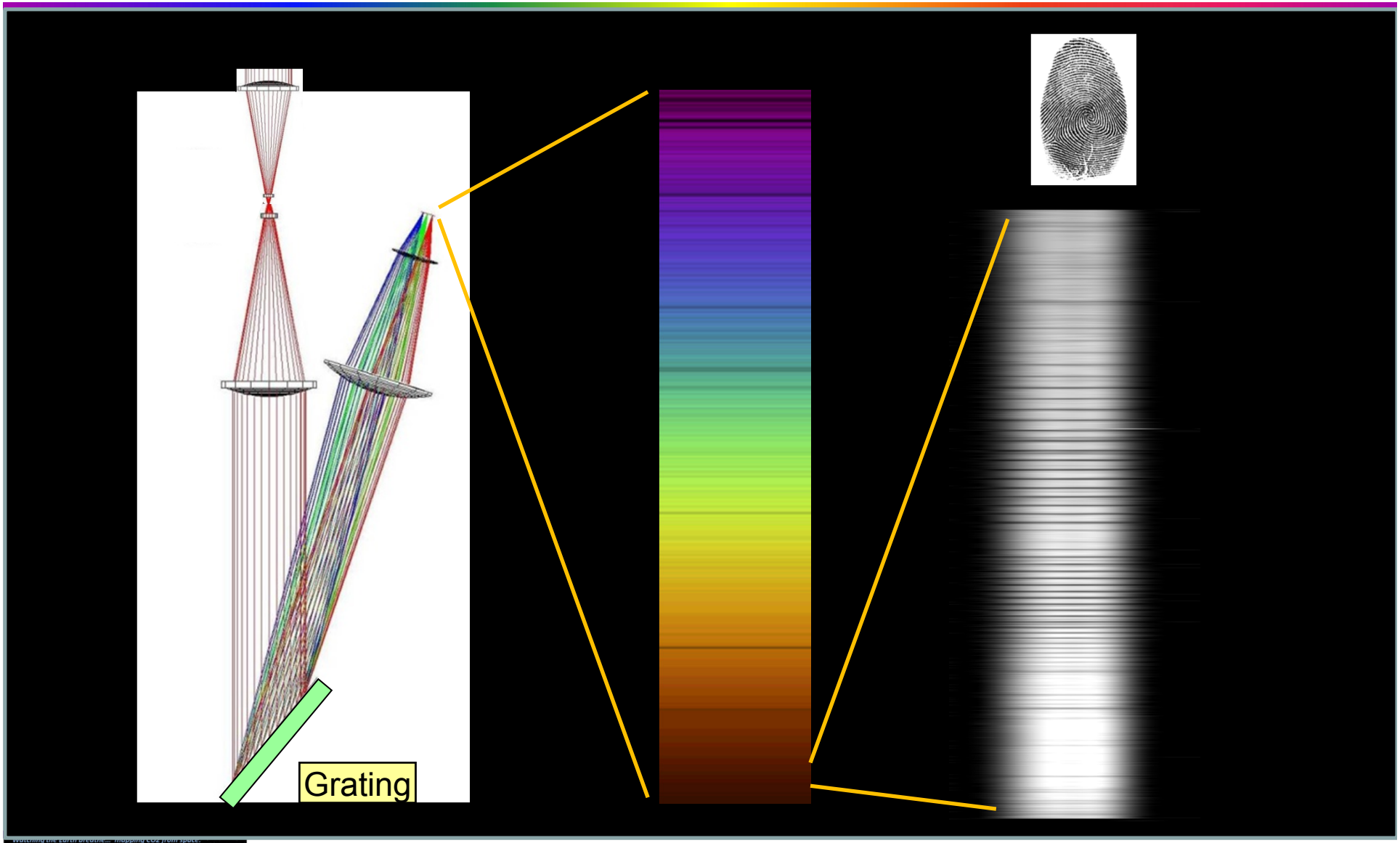
We can only manage what we can measure

Plumes from medium-sized power plants (4 MtC/yr) elevate X_{CO2} levels by ~2 ppm for 10's of km downwind [Yang and Fung, 2010].



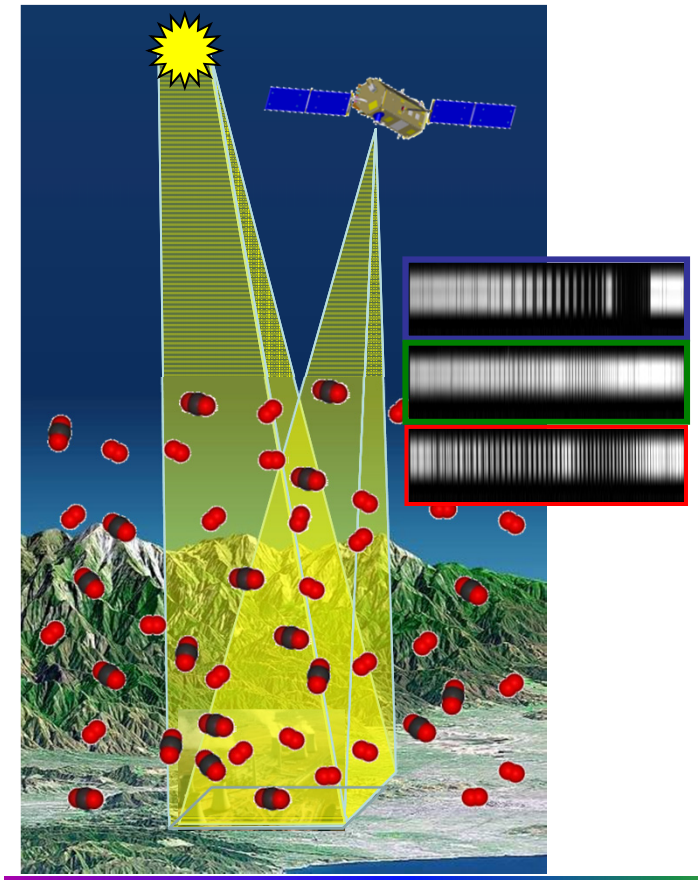
These variations are superimposed on a background of "**CO_2 weather**"

Measuring an Invisible Gas from Space

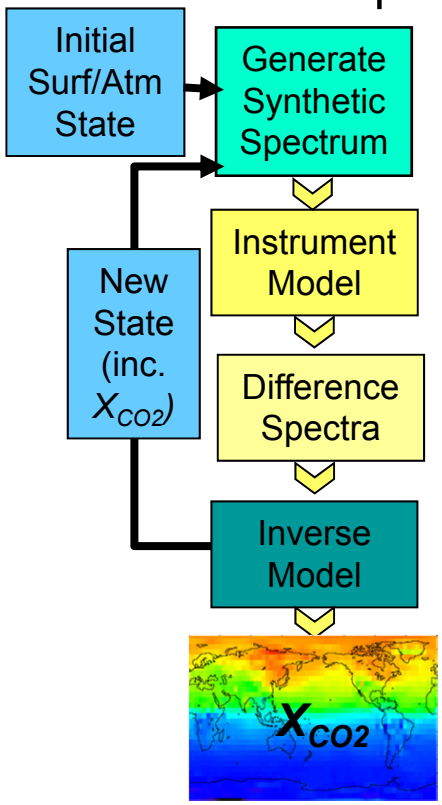


Measuring CO_2 from Space

- **Record** spectra of CO_2 and O_2 absorption in reflected sunlight



- **Retrieve** variations in the *column averaged CO_2 dry air mole fraction, X_{CO2}* over the sunlit hemisphere



- **Validate** measurements to ensure X_{CO2} accuracy

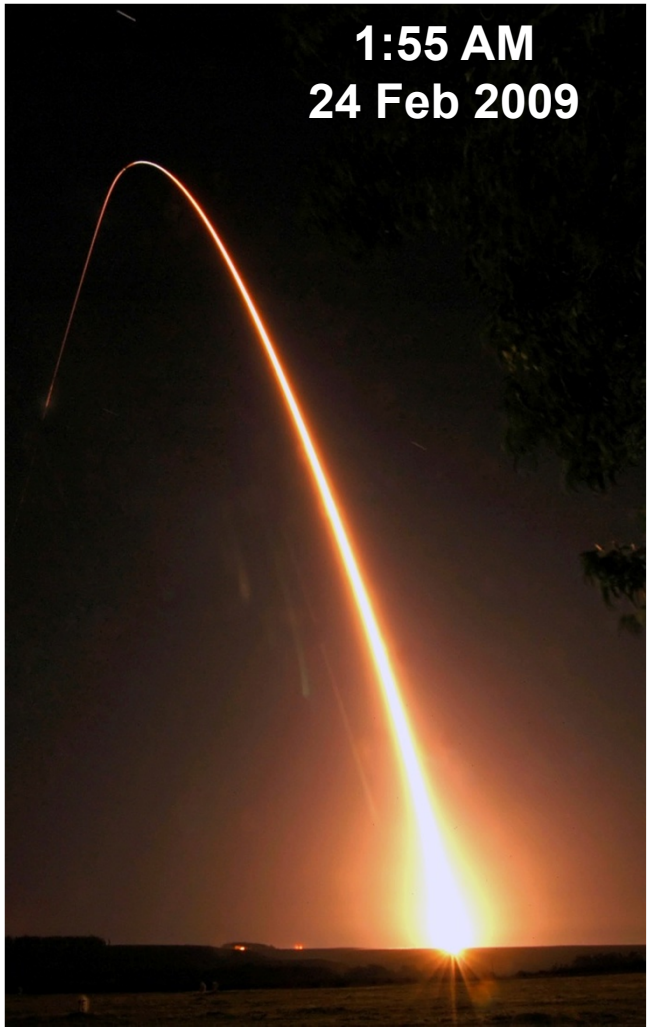
The Loss of OCO and the Birth of OCO-2

- NASA's Orbiting Carbon Observatory (OCO) was designed to provide the measurements needed to estimate atmospheric CO_2 with the sensitivity, accuracy, and sampling density needed to quantify regional scale carbon sources and sinks over the globe

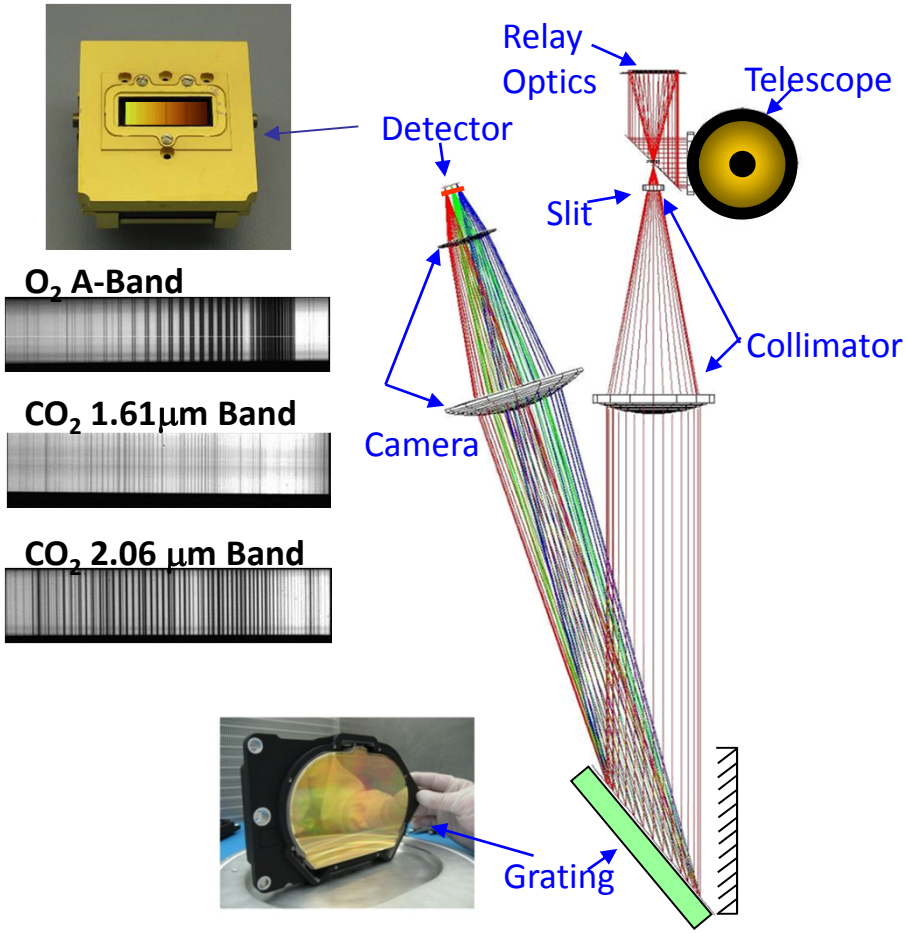
- February 2009: The OCO spacecraft was lost when its launch vehicle's fairing failed to open

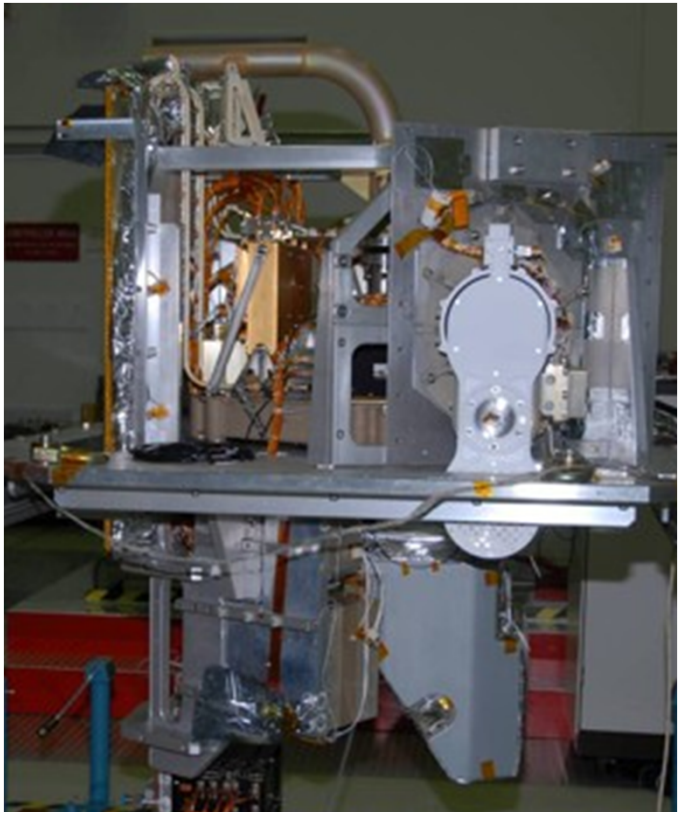
- December 2009: The U.S. Congress directed NASA to restart the OCO Mission

- The OCO-2 spacecraft bus and instrument are currently on track for a 2013 launch



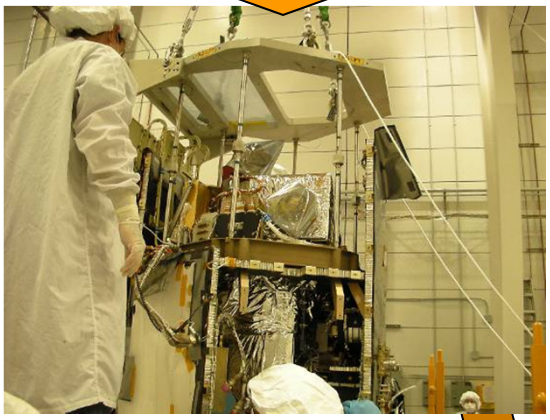
The OCO Instrument Will Make Precise Carbon Dioxide Measurements from Space

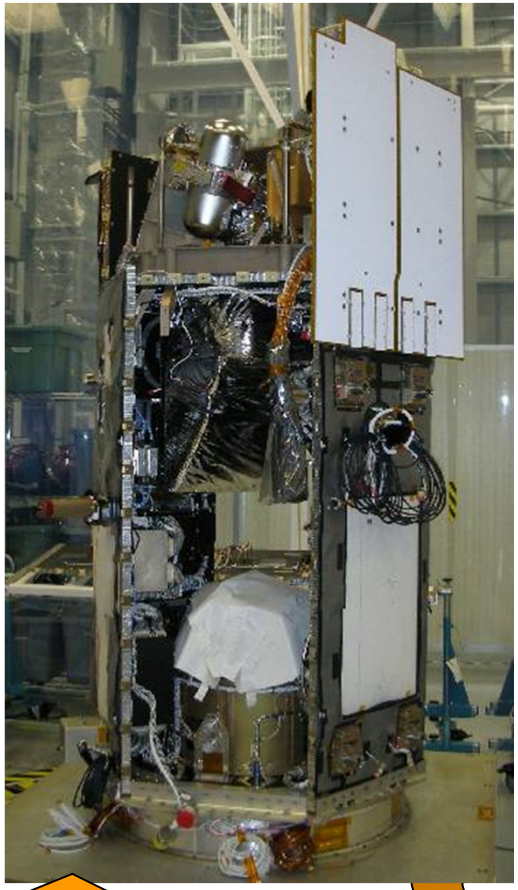




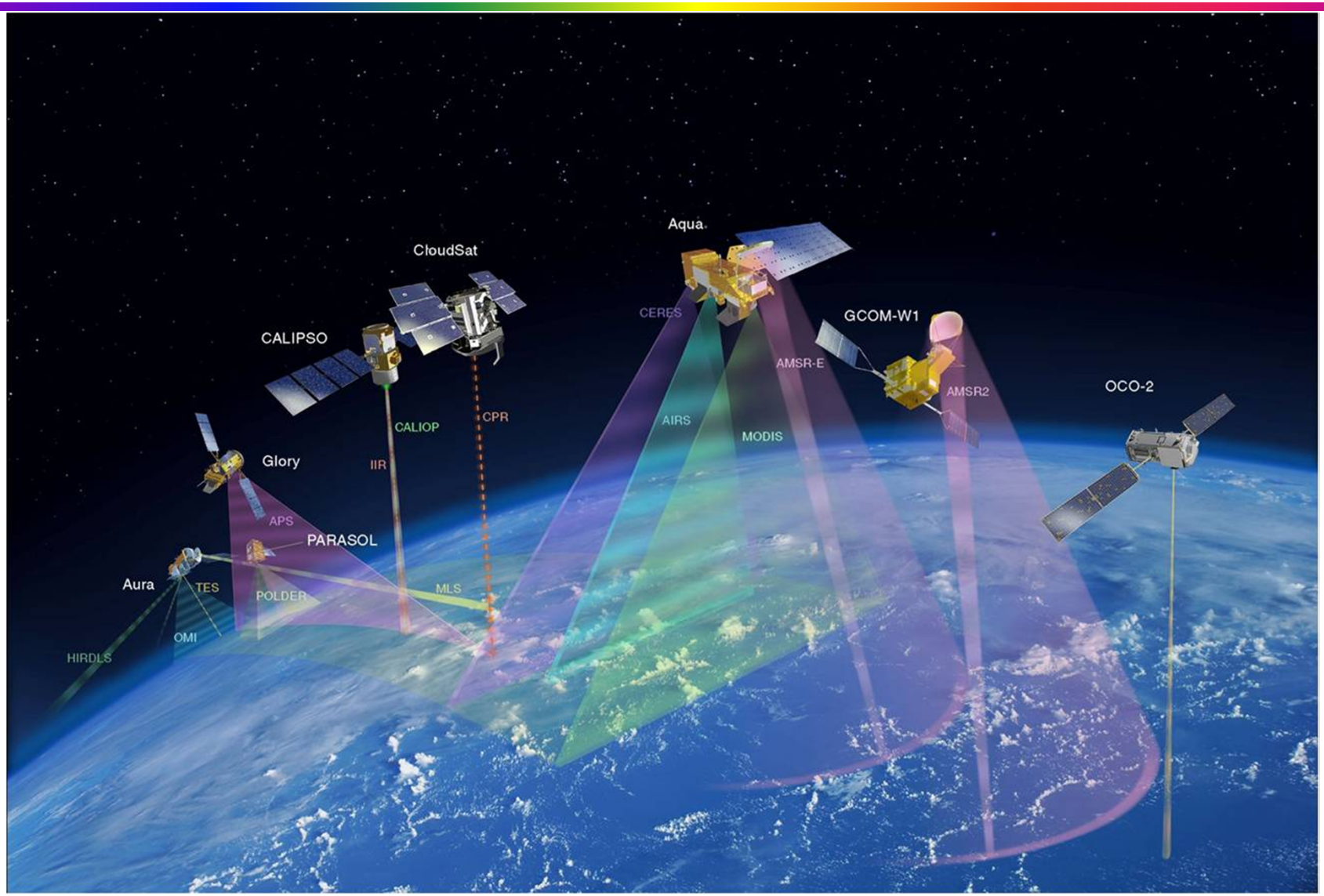
The OCO instrument uses three high-resolution grating spectrometers to measure the absorption of reflected sunlight by CO_2 and oxygen

Instrument + Spacecraft Bus = Observatory

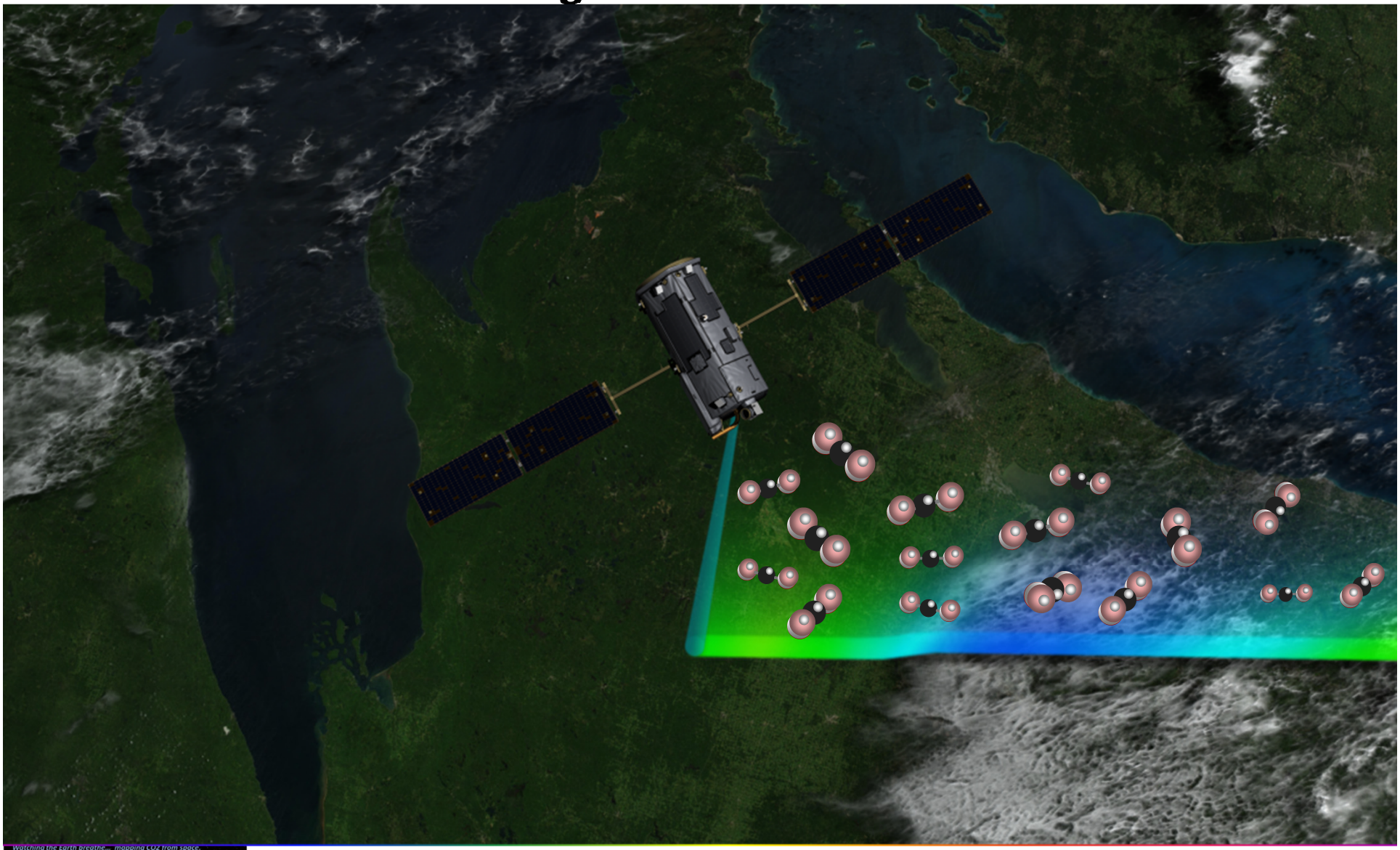




Flying in Formation in the A-Train



The Orbiting Carbon Observatory: Watching the Earth Breath



Watching the Earth Breathe... mapping CO2 from space.

OCO Orbiting Carbon Observatory